AD-A114 323 NAVAL CIVIL ENGINEERING LAB PORT HUENEME CA F/G 11/8
WASTE-OIL BOILER FIRING DEMONSTRATION AT NAS MIRAMAR, SAN DIEGO--ETC(U)
JAN 82 T T FU, R S CHAPLER
UNCLASSIFIED NL

1 of 1
AD A
114323

(13)

TN NO: N-1618

TECHNICAL

TITLE: WASTE-OIL BOILER FIRING DEMONSTRATION AT NAS MIRAMAR, SAN DIEGO, CALIF.

AUTHOR: T. T. Fu and R. S. Chapler

DATE: January 1982

SPONSOR: Chief of Naval Material

PROGRAM NO: Z0350-01-311

NOTE

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

**REPORT DOCUMENTATION PAGE** — READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER | TN-1618 |
| 2. GOVT ACCESSION NO. | DN687067 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) | WASTE-OIL BOILER FIRING DEMONSTRATION AT NAS MIRAMAR, SAN DIEGO, CALIF. |
| 5. TYPE OF REPORT & PERIOD COVERED | Final; May 78 – Sep 81 |
| 6. PERFORMING ORG. REPORT NUMBER | |
| 7. AUTHOR(s) | T. T. Fu and R. S. Chapler |
| 8. CONTRACT OR GRANT NUMBER(s) | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | NAVAL CIVIL ENGINEERING LABORATORY<br>Port Hueneme, California 93043 |
| 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS | 64710N; Z0350-01-311 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS | Chief of Naval Material<br>Washington, DC 20360 |
| 12. REPORT DATE | January 1982 |
| 13. NUMBER OF PAGES | 26 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | |
| 15. SECURITY CLASS (of this report) | Unclassified |
| 15a. DECLASSIFICATION DOWNGRADING SCHEDULE | |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Waste oils, fuel oil reclaimed (FOR), boiler fuel, liquid fuel, alternate fuel, combustion, pollutant emissions, energy conservation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The waste oils generated in the San Diego area were tested in boilers at NAS Miramar, San Diego, Calif. Approximately 4 million gallons of waste oils have been consumed during a period of more than 3 years. Results show that all four types of waste oils tested can be successfully fired in the same manner as commercial grade No. 2 fuel oil if they are reasonably free of water and sediment. No modifications for existing boiler equipment or changes in

continued

20. Continued

standard operating procedures are necessary. No unacceptable environmental emissions were observed. Due to the contaminants in the waste oils, more than normal effort is sometimes required to clean the oil strainers and the boilers' fireside surfaces. The existing practice for processing waste oils is reasonably satisfactory. Heating the waste oils to further remove water and sediment appears to be only an added cost and may be eliminated when a minimum specification for the waste oil is developed.

Library Card

Naval Civil Engineering Laboratory
WASTE-OIL BOILER FIRING DEMONSTRATION AT NAS MIRAMAR, SAN DIEGO, CALIF. (Final), by T. T. Fu and R. S. Chapler
TN-1618 26 pp illus January 1982 Unclassified

1. Waste oils 2. Oil-fired boilers I. Z0350-01-311

The waste oils generated in the San Diego area were tested in boilers at NAS Miramar, San Diego, Calif. Approximately 4 million gallons of waste oils have been consumed during a period of more than 3 years. Results show that all four types of waste oils tested can be successfully fired in the same manner as commercial grade No. 2 fuel oil if they are reasonably free of water and sediment. No modifications for existing boiler equipment or changes in standard operating procedures are necessary. No unacceptable environmental emissions were observed. Due to the contaminants in the waste oils, more than normal effort is sometimes required to clean the oil strainers and the boilers' fireside surfaces. The existing practice for processing waste oils is reasonably satisfactory. Heating the waste oils to further remove water and sediment appears to be only an added cost and may be eliminated when a minimum specification for the waste oil is developed.

CONTENTS

## INTRODUCTION

Large quantities of waste oils are routinely generated by the Navy's shore facilities. The composition and properties of these waste oils vary, depending on the particular function and activities involved at the source of generation. Usually these waste oils are unsuitable for the intended original applications. The possibility of utilizing this valuable energy resource for firing boilers was therefore studied. A range of laboratory tests have been conducted, and waste oils have been determined to be a satisfactory boiler fuel*.

Due to the unique combination of waste oil characteristics and existing burner equipment at each facility, details for firing waste oils must be worked out individually prior to their use on a regular basis. Therefore, two demonstration sites for waste oil boiler firings were recommended by Fu and Chapler:*

1. Naval Weapons Center (NWC), China Lake, Calif. NWC boilers are fired on No. 6 fuel oil (a heavy oil), and the waste oils generated there are relatively light and small in quantity compared to the boiler plant fuel requirement. Testing of blends of the waste oil into the regular fuel oil was recommended.
2. Naval Air Station Miramar (NAS Miramar), San Diego, Calif. NAS Miramar boilers are fired on light fuel oils. Large quantities of waste oils are generated in the San Diego area (primarily from ship operations). Testing of the ship's waste oils by direct firing was recommended.

For the work described in item 1 above, extensive tests were conducted using an in-service boiler at NWC. Both schemes of batch blending and in-line blending of waste oils into the regular No. 6 fuel oil were satisfactorily demonstrated. No modifications to the existing boiler equipment and fuel system component were necessary. No difficulties were encountered in firing these blends nor were there excessive stack emissions or maintenance requirements. The results and experimental details are described in TN-1580.**

This document is a final report on the work described in item 2 above.

---

*Civil Engineering Laboratory. Technical Note N-1570: Utilization of Navy-generated waste oils as boiler fuel - Economic analysis and laboratory tests, by T. T. Fu and R. S. Chapler. Port Hueneme, Calif., Feb 1980.

**__________. Technical Note N-1580: Waste oil boiler firing demonstration at NWC, China Lake, Calif., by T. T. Fu and R. S. Chapler. Port Hueneme, Calif., Jun 1980.

## BACKGROUND

NAS Miramar's boiler plant provides steam for the entire station. There are three water-tube boilers in the plant, each having a maximum operating capacity of 30,000 pounds of steam per hour. Due to the nature of the base operations, there is a sizeable year-round steam demand. For example, the actual steam demand and fuel consumption profiles for FY79 and FY80 are portrayed in Figure 1. For convenience of comparison, the annual consumptions of energy and waste oils are summarized in Table 1. These figures show that the NAS Miramar boiler plant has a total waste oil burning capacity of about 2 million gallons per year.

The waste oils generated in the San Diego area are from the following four sources:

| | |
|---|---|
| Miramar Naval Air Station: | Primarily contaminated JP-5 from aircraft operations. |
| San Diego Naval Station: | Primarily oils recovered from bilge and ballast waters from ship operations. |
| North Island Naval Air Station: | Combinations of oils recovered from ship and aircraft operations and industrial waste treatment. |
| Point Loma Reclamation Facility: | Ship's waste oils with water and solids removed by heating and settling. This oil is known as FOR (Fuel Oil Reclaimed). |

All these waste oils are mixtures of contaminated fuel oils, used lubricants, cutting oils, hydraulic fluids, solvents, etc. The largest quantities are obtained from ship oily waste (approximately 93%) and the remaining from shore activities. Because of the origin, all these waste oils are low in viscosity and gravity (or density) and may be regarded as a type of light fuel oil.

According to an estimate by Young*, the total waste oils generated in the San Diego area are about 8 million gallons per year. This figure, although believed to be high, serves to indicate that the achievable benefit or savings by substituting waste oils for conventional boiler fuels is unquestionably high. NAS Miramar has both a large energy requirement and the capability to utilize the waste oils and therefore was selected for demonstrating direct firing of the waste oils generated in the San Diego area

In May 1978, the Naval Civil Engineering Laboratory (NCEL) proposed to Public Works, NAS Miramar (PW/M) to use one of their boilers to demonstrate firing of the waste oils generated at NS San Diego. Discussions led to the signing of a memorandum of understanding between NCEL and PW/M in September 1978. The following items were agreed upon:

---

*Personal communications with Jeffery B. Young, Pountney & Young, Inc., San Diego, Calif., Nov 1980.

1. PW/M would designate a boiler and an underground fuel storage tank for NCEL to conduct the tests and provide personnel support to assist in carrying out the planned work during normal operating hours.
2. NCEL would fund PW/M to design and install a separate fuel-handling system between the designated tank and boiler so that any test work would not interfere with normal plant operation. All other existing systems for the boiler would remain unchanged.
3. NCEL would obtain the waste oils and plan and conduct the tests, pay any extra expenses incurred during the tests, and report the test results.

## BOILER FACILITY

The No. 4 boiler and the north tank at Building K-212 were designated by PW/M for the tests. The unit is a water-tube, package-type boiler that produces 125 psig saturated steam at 30,000 lb/hr maximum operating capacity. It has two burners fired either on natural gas or light fuel oil with a steam atomization nozzle. The fuel tank is underground and has a 30,000-gallon capacity. Pursuant to the agreement, PW/M designed and installed a fuel-handling system between this tank and the boiler. It consists of a water-stripping pump to remove water from the tank bottom, a steam-driven fuel transfer pump, fuel supply and return lines, flow meters, and pressure regulators. The overall arrangement is shown schematically in Figure 2. As seen, the burner may draw oil either from the north tank or from the main fuel supply simply by operating the appropriate valves. The overall view of the boiler is shown in Figure 3, while the fuel pump and burners are shown in Figure 4.

The existing instrumentation consists of flowmeters for steam, feedwater, and fuel; stack gas temperature and oxygen concentration measurements; and miscellaneous pressure and temperature gages. NCEL installed an automatic instrumentation package to continuously monitor and measure $O_2$, $NO_x$, and CO concentrations in the stack gas. The schematic and installation of this instrumentation package are shown in Figures 5 and 6 respectively.

## WASTE OILS

NCEL initially obtained a written agreement from NS San Diego to furnish, at no cost, the waste oils generated from their waterfront operations. PW/M took the responsibility of hauling the waste oils to NAS Miramar and was given priority in using the waste oils generated at NS San Diego. Whenever practical, the oil was taken first to the holding tanks located at the NAS Miramar Fuel Division for further removal of water and solids by gravitational settling. The oil on the top was then hauled to the boiler plant. NAS Miramar also obtained FOR from Point Loma, San Diego, at $0.35 a gallon. This oil is of better quality because it is fairly uniform and contains less water and sediment.

Later, toward the end of the tests reported here, some waste oils were obtained from NAS North Island.* This oil was an inferior material. It was difficult to ignite and readily plugged up fuel strainers due to the large amounts of suspended water and solids in the industrial wastes. To improve the quality and to help accelerate the settling process, it was blended with the contaminated JP-5 available from NAS Miramar in a proportion of about one part JP-5 to five parts waste oil, and was allowed to settle for several days. After removal of the separated water and sediments (usually 15 to 20%), the blended material was satisfactory for boiler firing.

In summary, PW/M has used all four types of waste oils described above in its boiler plant. Due to the unknown nature of the waste streams from which the waste oils are recovered, their properties vary from one batch to another and precise determination is not considered meaningful. Fortunately, this is not necessary because from the standpoint of using them as boiler fuels, the requirements of interest are that the waste oils be combustible and contain no ingredients that would have adverse effects on boiler components and the environment. For this reason, the basic properties of random samples of FOR and the waste oils most available and used in large quantities (i.e., ship's waste oil) are compared with the specifications for No. 2 fuel oil in Table 2. Qualitatively, these oils, other than being close to black and having a somewhat higher BS&W and ash content, appear to be the same as No. 2 fuel oil.

A collection of the data for the waste oil samples analyzed by the Petroleum Laboratory, Naval Supply Center Point Loma Annex, San Diego, Calif., during FY80 and FY81 was obtained, and the relevant information is summarized in Table 3. Note that these waste oils are reasonably close to each other in properties. Although some of the samples contain higher water and sediment than FOR, there appears to be only a very weak justification for further treatment of the waste oils by the reclamation facility which provides only heat to the oil to accelerate gravitational settling, an unnecessary added cost. Navy use of heavy, high-viscosity fuel oils has diminished significantly in recent years; therefore, the waste oils generated are primarily light and of low-viscosity. Gravitational settling alone can effectively separate contaminant water and solids from the oil without the heating normally required for the more viscous fuels. At present, no guidelines on the limits of properties for waste oils are available. It is clear that, with some guidelines developed for processing and handling waste oils, the Navy can easily eliminate the waste oil reclamation facility.

---

*The waste oils from NAS North Island are from buildings 788 and 426. The former is a salvage facility for the fuel farm and the latter is an industrial waste treatment plant. The salvaged fuel sometimes contains some low-flash fuel such as JP-4. In order to bring the flash point up, blending with high-flash point fuel is done at the Miramar fuel farm. The material from the industrial waste plant usually contains large amounts of water and suspended solid material and does not burn readily.

Contaminants in the waste oils can be harmful to the environment and boiler components. Analyses of three waste oil samples were made to determine the type and amount of contaminants in each. The results are summarized in Table 4. Judging from the origin of the waste oils available in the area, the amount of contaminants in the waste oils should vary from the least in FOR to the most in the NAS North Island waste oil. The results in Table 3 show that this is indeed the case.

The much higher contaminant levels in the waste oil from NAS North Island are most likely from industrial wastes. It is reasonable to expect that the chloride comes mostly from seawater, the iron and copper from steel and copper ship components or simply the rusts from these components in contact with the oil, and the rest of the contaminants from industrial waste streams. Comparing the amount of contaminants in FOR, it is also reasonable to expect that except for sulfur, a significant percentage of these contaminants can be removed from the waste oils through the FOR treatment (heating and gravitational settling). The harmful contaminants, such as chromium, lead, and cadmium, are well below the levels that would be of concern.

Samples of these four types of waste oils were also analyzed using a Beckman IR 4250 spectrophotometer. The absorption spectra for each sample of oil were obtained for both a 0.1-mm path length and that squeezed between two salt crystals. The results show that these waste oils are all practically the same and have the same characteristic features as aliphatic hydrocarbons (typical of conventional type fuel oils).

Based on the above results, it is safe to consider that the waste oils generated in the San Diego area are practically the same as commercial grade No. 2 fuel oil. With as much water and sediment removed as possible by settling and straining, these waste oils should be adequate substitutes for No. 2 fuel oil. No significant modification to the existing boiler systems should be anticipated.

## BOILER PLANT OPERATION

The operating profiles of the NAS Miramar boiler plant (Building K-212) are shown in Figures 7 and 8. Figure 7 shows the steam export (demand) and fuel consumption profiles during the days of highest and lowest levels in FY80. Figure 8 shows the same profiles during the highest and lowest months. Comparing these two figures, note that the highest demands were between 0600 and 1700 during week days when practically all the base activities take place. The demands at other times are relatively stable and lack characteristic changes.

There are three boilers in the plant: one is always on-line to carry the total or main load; one is in a standby status to provide for fluctuating steam demand exceeding the capacity of the first boiler; and one is either idle or being maintained. During warm months (e.g., September), the steam demand level is practically constant which represents the steady daily requirements of the base plus any losses due to leakage. Therefore, one boiler is sufficient during these months, and it is fired at 10,000 lb/hr or one-third the boiler's capacity or higher.

During cold months, two boilers are often required: one at full output capacity and the other at varying output to meet any fluctuating steam demands. For example, considering the case as shown by the top curve in Figure 8, two boilers will be required: one boiler would be always on at full load and one would carry a varying load between 0 and 11,000 lb/hr. During mild weather, the steam demand is likely below the capacity of one boiler and may vary between 10,000 and 30,000 lb/hr. Since all the boilers must be routinely maintained, they are normally operated on a rotating schedule; the full spectrum of load conditions will always be experienced by all the boilers during the period between overhauls (normally 2,500 boiler operating hours at NAS Miramar). Therefore, monitoring the operation of any one of the three boilers for a period corresponding to one overhaul cycle would yield the data needed in order to determine the operational requirements and environmental effects of waste oil burning.

## TEST RESULTS

The No. 4 boiler originally assigned for testing purposes was temporarily unavailable at the time when the test setup was ready because of routine maintenance. Since all three boilers in the plant are identical units, the actual test work began with the No. 2 boiler. All four types of waste oils were found to be satisfactory for boiler firing and could be handled in the same manner as for No. 2 fuel oil. No irregularities were observed other than the requirements for more frequent cleaning of the fuel strainers and the occasional stripping of any water settled in the bottom of the tank.

The boiler was operated routinely from 21 April 1979 to 6 October 1980 for a total of 2,418 operating hours. As discussed earlier, the boiler experienced all types of load variations. During normal operation, there was no visible smoke from the stack; the oxygen concentration in the stack or flue gas varied between 5% and 6% with occasional excursions up to 8% and down to 3%. The stack gas temperature increased with the steam load as expected, but it also depended on the individual boiler. The following is an illustration of such a variation during a cold day, 11 January 1980, between No. 2 and No. 4 boilers (the variation of the outside air temperature during the 24-hour period was between 58°F and 62°F).

| Boiler | Steam Load (lb/hr) | Stack Gas Temp. (°F) |
|---|---|---|
| No. 2 | 18,600 - 25,200 | 550 - 620 |
| No. 4 | 15,000 - 21,600 | 420 - 500 |

The CO (carbon monoxide) level was always low and was in the range of 10 to 20 ppm. The $NO_x$ (nitrogen oxides) concentration was also low and was in the range of 80 to 120 ppm (corrected to 3% oxygen). These are recorded on a strip chart; a typical output on this chart is shown in Figure 6. The automatic calibration feature of this instrumentation package, the levels of $O_2$, $NO_x$, and CO when the burner fuel/air ratio

control is operated on both automatic and manual modes, and the variations of CO and $NO_x$ resulting from the sudden drop of $O_2$ levels are all illustrated. Since these emissions are not regulated for boilers of this size, and since the emissions were well below regulated levels (e.g., 225 ppm is the maximum allowable $NO_x$ emission for boilers greater than 50 million Btu/hr burning liquid or solid fuels), the waste oils tested were all satisfactory from an environmental standpoint.

After 2,418 hours of operation, the boiler was shut down for routine maintenance. During this period approximately 37 x $10^6$ pounds of steam was exported and 400,000 gallons of waste oils had been consumed. When the interior of the boiler was inspected, a 1-to-2-mm-thick, white powdery, friable deposit was found on the boiler's fireside surfaces. Burning clean light fuel oil or natural gas does not generate much deposit on the boiler's fireside surfaces, but this deposit situation is considered better than burning low-grade, heavy fuel oils (e.g., No. 6 oil). In the region closest to the flame, there was a greenish, fused, scaly material (looked like peeling paint) deposited over the white deposit (Figure 9).

According to the boiler operators, the white deposit was not uncommon when burning waste oils, but the greenish material had not been observed before. Samples of these deposits were brought back to NCEL for analysis. Energy-dispersive X-ray analyses of both the green and white deposit samples show that they were similar. A result of these analyses is shown in Figure 10. Note that the major peaks were generated for silicon, phosphorus, sulfur, and calcium. Smaller quantities of iron, zinc, copper, and potassium were also detected. The white, powdery deposit is slightly acidic, which is typical of oil-ash products. The greenish color of the fused deposit is believed to be due to some zinc and copper compounds.

Since the waste oils from NAS North Island were burned during the last part of the tests and the greenish material was apparently deposited last, it is reasonable to believe that this greenish material was from the North Island waste oils, which contained relatively large quantities of zinc and copper as illustrated in Table 4. (This oil was recovered from mixtures of industrial wastes, bilge waters, contaminated fuels, etc., at the treatment plant. Excessive contamination of the oil was not unexpected.)

Both the white and greenish deposits could be easily brushed off and did not appear to cause any physical damage to the boiler's fireside surfaces. Approximately 50% more time would be required to clean the boiler's fireside surfaces after burning waste oils than burning regular fuels.

Since no major difficulties were encountered as the program proceeded, the test work was extended to burn the waste oils in the other boilers of the plant. So far, the available waste oils have not been sufficient to furnish the full demand of the boiler plant, and natural gas has been used at times to make up the deficiency. The extent of waste oil burning at NAS Miramar can be illustrated by the quantities of waste oils, including FOR, that have been hauled in by the Fuel Division during the last four years:

Waste Oil (gal)

| FY | Naval Station | North Island | Pt. Loma (FOR) | Total |
|---|---|---|---|---|
| 78 | 105,313 | 0 | 0 | 105,313 |
| 79 | 620,435 | 0 | 819,350 | 1,439,785 |
| 80 | 713,500 | 236,000 | 320,000 | 1,269,500 |
| 81 | 774,300 | 204,700 | 225,000 | 1,204,000 |
| Total | 2,213,548 | 440,700 | 1,364,350 | 4,018,598 |

## CONCLUSIONS

Approximately 4 million gallons of waste oils generated in the San Diego area have been consumed by the boilers at NAS Miramar during a period of more than 3 years. Results show that these waste oils are satisfactory substitutes for regular fuel oils and can be fired without requiring modifications to the existing equipment. No apparent adverse effects to either the boiler components or the environment were observed.

To prepare for firing, the waste oils should be stripped of water and sediments by gravitational settling. Experience has shown that the elaborate and costly method of processing Fuel Oil Reclaimed, by heating and settling, is unnecessary. The additional maintenance efforts associated with waste oil firing are:

1. More frequent cleaning of the fuel strainers
2. Approximately 50% more effort to clean the boiler's fireside surfaces

The extent of the additional work described above varies according to the particular fuel used. This effort is considered minor, however, because it is a routine part of boiler operation.

## RECOMMENDATIONS

1. The majority of the Navy's boilers are small, fire-tube, unmanned units. The total fuel requirements for these boilers are therefore, very significant. Because of the success in firing waste oils in the boilers at NAS Miramar (large size, water-tube, normally attended), a logical extension to the overall effort would be to conduct demonstration tests using small firetube boilers. The Marine Corps Station at Camp Pendleton has more than 500 small boilers in operation. In light of the above and because of the very large quantities of waste oil generated in the San Diego area (as estimated by Young*), a firing demonstration should be conducted at Camp Pendleton.

---

*Personal communications with Jeffery B. Young, Pountney & Young, Inc., San Diego, Calif., Nov 1980.

2. The present practice of handling waste oils provides satisfactory boiler fuels without the need for a dedicated facility to further separate the water and sediments by heating. Experience shows that this added cost may be readily eliminated if proper quality control is exercised. Development of a minimum specification for this type of boiler fuel is recommended.

## ACKNOWLEDGMENT

Contributions and cooperation to planning and conducting the tests are gratefully acknowledged for personnel of Public Works and Fuel Division of NAS Miramar: Messrs. Albert Wong, Harold Dowdy, Bill Neipp, Al Valdez, Joe Ford, and George Ransom.

Table 1. Annual Consumptions of Energy and Waste Oils for Boilers

| FY | Total MBtu | Waste Oils | | Waste Oils / Total (%) |
|---|---|---|---|---|
| | | MBtu | Gallons | |
| 79 | 286,839 | 245,988 | 1,773,527 | 85.8 |
| 80 | 301,836 | 180,161 | 1,298,929 | 59.7 |

Notes:

1. The lower waste oil consumption in FY80 than in FY79 was due to availability. For example, lack of squadron activity on base or ship in port will result in reduced waste oil generation.

2. The energy values used for computation are 1,031 Btu/SCF for natural gas and 138,700 Btu/gal. for fuel oil.

Table 2. Comparison of Random Samples of FOR and Waste Oils With Specification for No. 2 Fuel Oil

| Properties | No. 2 Fuel Oil (Spec) | FOR | Ship's Waste Oil |
|---|---|---|---|
| Gravity, API at 60°F | >30 | 34.4 | 34.0 |
| Viscosity, Cs at 104°F | 2.0 - 3.6 | 4.0 | 4.7 |
| Flashpoint, °F | 212 | 184 | 212 |
| BS&W, % vol | <0.10 | 0.1 | 0.1 |
| Ash, % wt | Trace | 0.068 | 0.057 |

Table 3. Basic Properties of Waste Oil Samples Analyzed by the Petroleum Laboratory, Point Loma (courtesy of Mr. H. F. Anderson)

| Sample No. | Gravity (API at 60°F) | Flash Point (°F) | Viscosity (Cs at 104°F) | W&S (%) | Ash (%) | Sulfur (%) | Cu Strip at 100°F |
|---|---|---|---|---|---|---|---|
| 80-422[a] | 34.3 | 184 | 3.0 | 0.7 | 0.075 | | |
| -423 | 34.5 | 184 | 2.5 | 0.7 | 0.062 | | |
| -424 | 34.8 | 182 | 3.8 | 0.5 | | | |
| -425 | 34.6 | 182 | 3.6 | 0.2 | | | |
| -426 | 34.9 | 190 | 3.8 | 0.1 | | | |
| -470 | 33.9 | 188 | 4.1 | 1.0 | | | |
| -471 | 33.8 | 188 | 4.1 | 1.0 | | | |
| -476 | 34.7 | 178 | 3.7 | 0.07 | 0.024 | | 4a |
| -536 | 34.6 | 182 | 3.6 | 0.04 | | | |
| -622 | 34.6 | 186 | 3.6 | 0.6 | | | |
| -931 | 35.2 | 174 | 3.3 | 2.4 | | | |
| -1059 | 34.9 | 170 | 3.7 | 1.6 | | | |
| -1206 | 34.0 | 212 | 4.7 | 0.1 | 0.057 | | |
| -1388 | 33.6 | 180 | 4.4 | 0.5 | | | |
| -1389 | 34.0 | >230 | 4.54 | 0.5 | | | |
| -1417 | 34.3 | 178 | 3.9 | 0.1 | | | |
| -1606 | 33.3 | 182 | 4.2 | 1.0 | | | |
| 81-44 | 34.0 | 180 | 4.0 | 0.1 | | 0.34 | |
| -211 | 35.7 | 210 | 3.6 | 0.02 | | | |
| -212 | 33.8 | 174 | 4.1 | 0.15 | | | |
| -528 | 32.9 | 170 | 4.7 | 2.2 | | 0.39 | |
| -724 | 33.2 | | | | | | |
| -755 | 35.7 | 168 | | 0.3 | | | |
| -796[a] | 35.7 | 170 | 3.3 | 0.04 | 0.015 | 0.40 | |
| -797 | 36.1 | >230 | 2.8 | 0.30 | 0.023 | 0.26 | |
| -841[a] | 34.9 | 174 | 3.2 | 0.2 | | | |
| -847[a] | 34.1 | 178 | 3.8 | 0.9 | 0.063 | | |
| -906 | 34.5 | 172 | | 0.6 | | | |
| -883 | 35.2 | 168 | | 0.1 | | | |
| -954 | 34.5 | 168 | | 0.8 | | | |

[a]FOR processed through the Point Loma heating facility.

Table 4. Contaminants in FOR and Waste Oils

| Contaminants | FOR Point Loma | Waste Oil | |
|---|---|---|---|
| | | NAS North Island | NS San Diego |
| Chloride, mg/l | 2.0 | 717.0 | 44.0 |
| Iron, mg/l | 16.9 | 2,300.0 | 358.0 |
| Zinc, mg/l | 22.5 | 543.0 | 33.3 |
| Chromium, mg/l | 0.35 | 94.0 | 1.0 |
| Lead, mg/l | 4.7 | 19.0 | 15.8 |
| Copper, mg/l | 0.99 | 267.0 | 2.8 |
| Cadmium, mg/l | <0.1[a] | 1.3 | 0.25 |
| Nickel, mg/l | 0.61 | 31.0 | 2.4 |
| Tin, mg/l | <0.3[a] | 1.6 | <0.3[a] |
| Sulfur, % | 0.36 | 0.4 | 0.4 |

[a]Not detected.

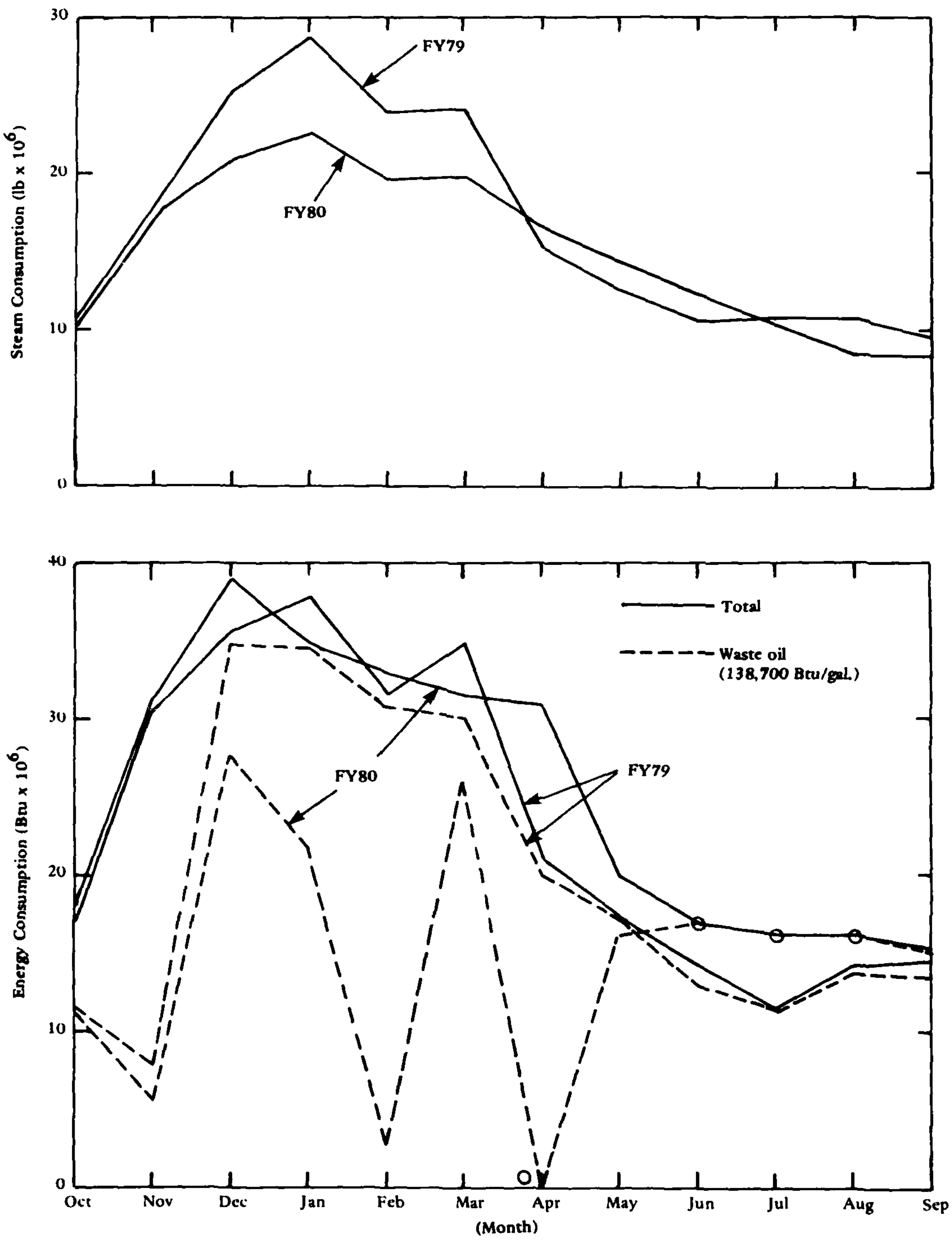



Figure 1. Steam and energy consumption profiles at NAS Miramar.

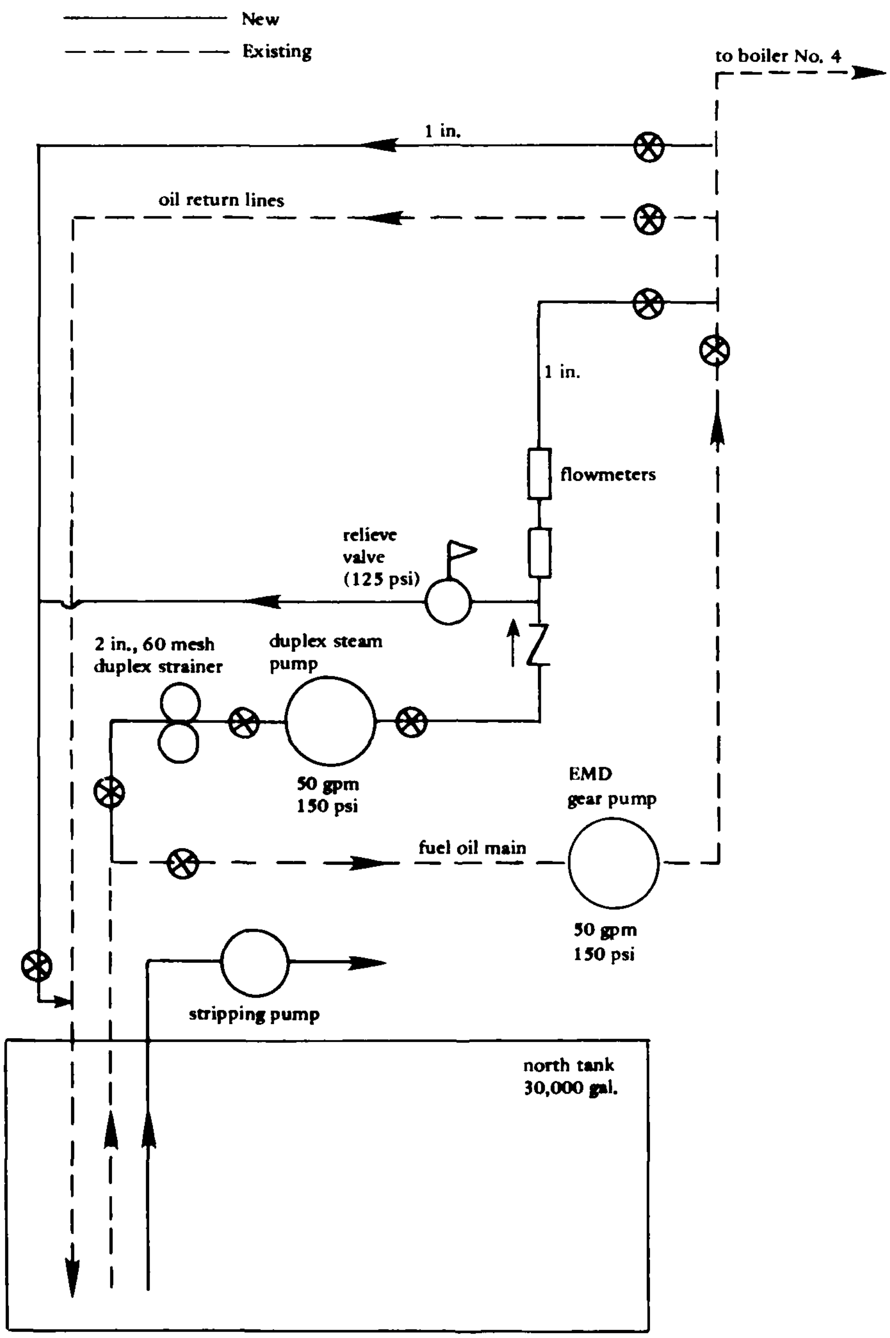
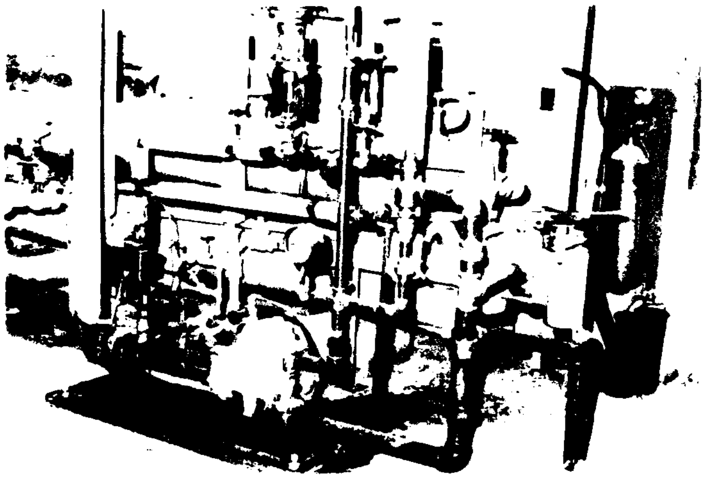
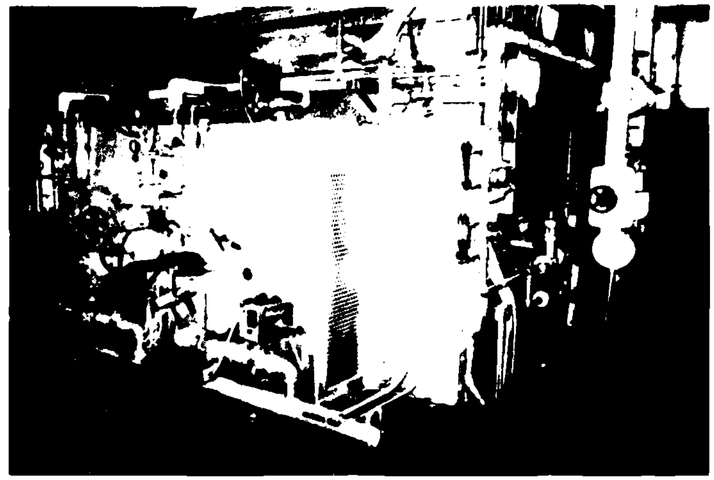



Figure 2. Schematic of fuel-handling system installed by PW/M.

Figure 3. Overall view of boiler.

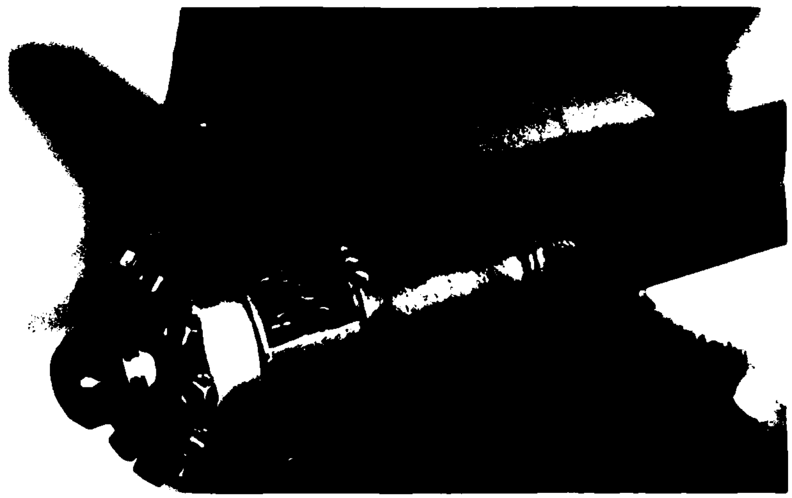


(a) Fuel pump



(b) Exterior view of burners

(c) Interior view of burners



(d) Oil gun

Figure 4. Fuel pump system and burner.

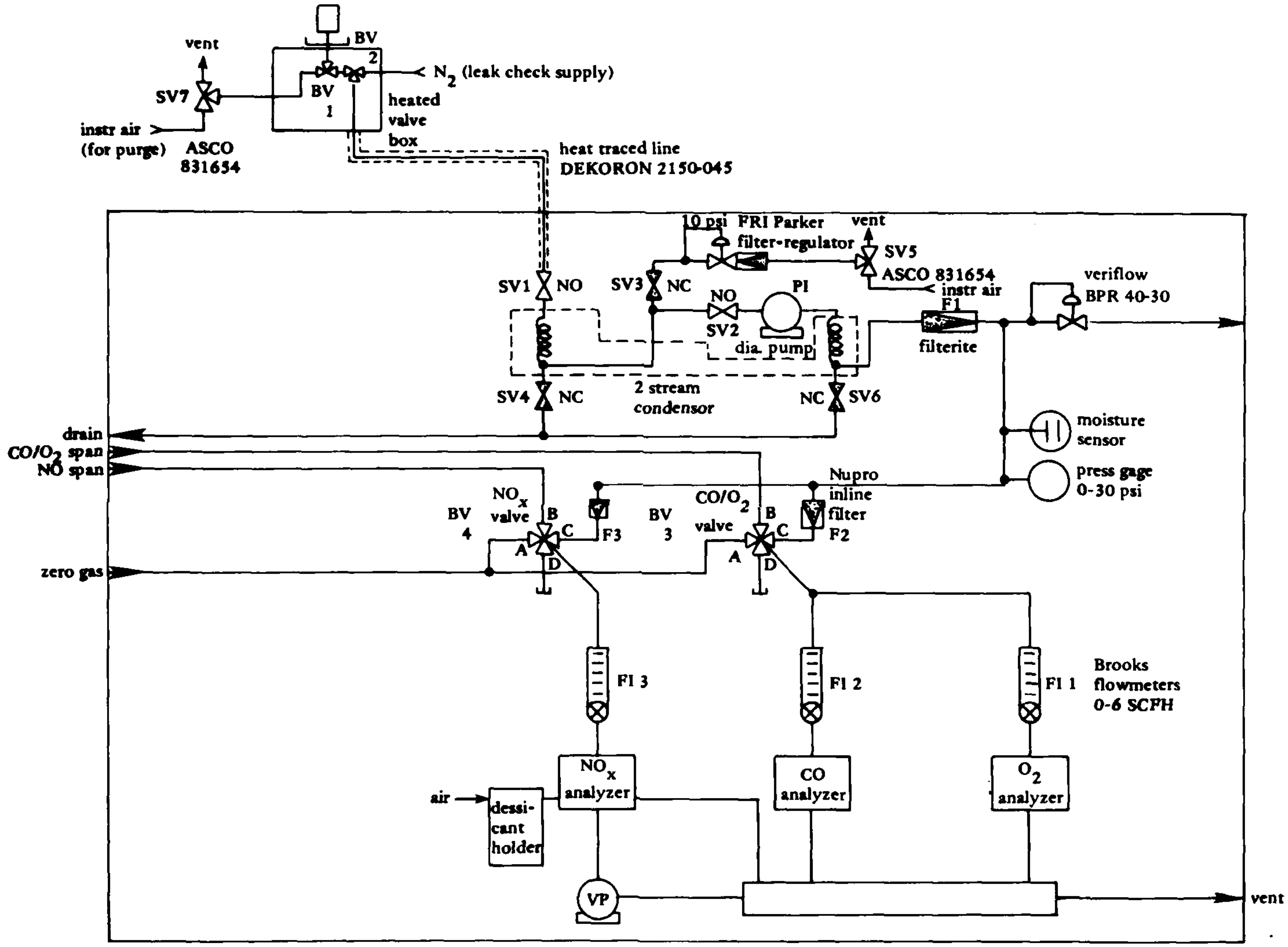
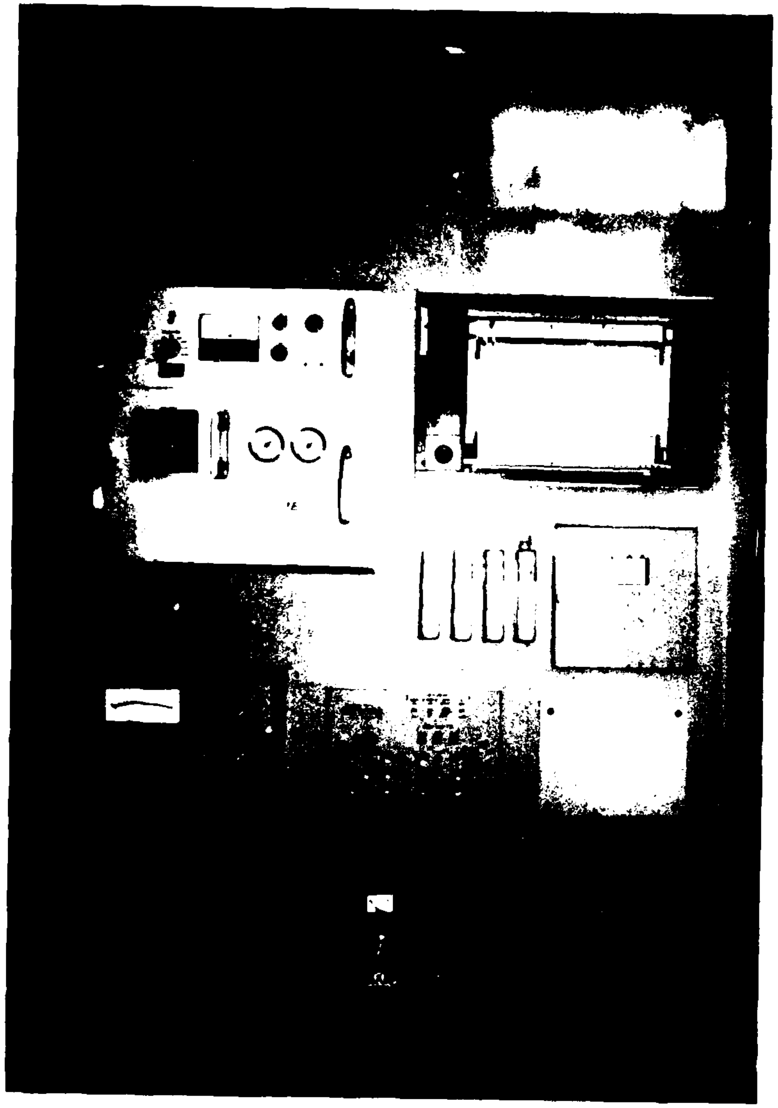
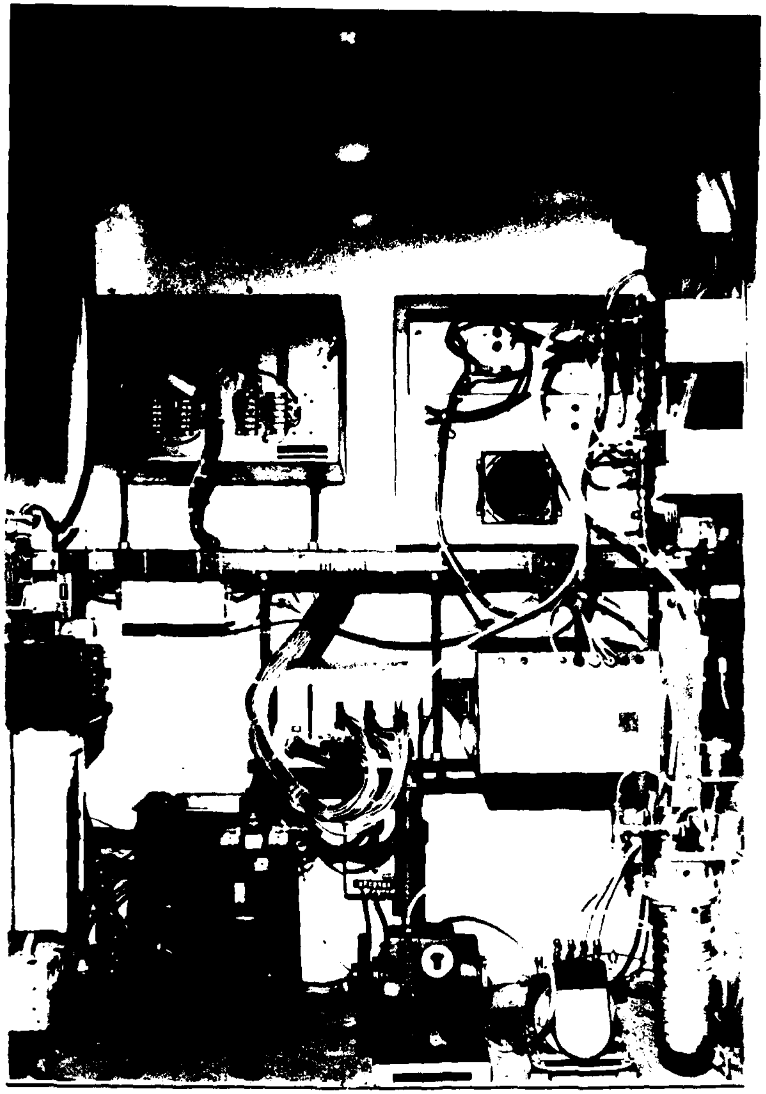



Figure 5. Schematic of automatic stack gas analysis system.



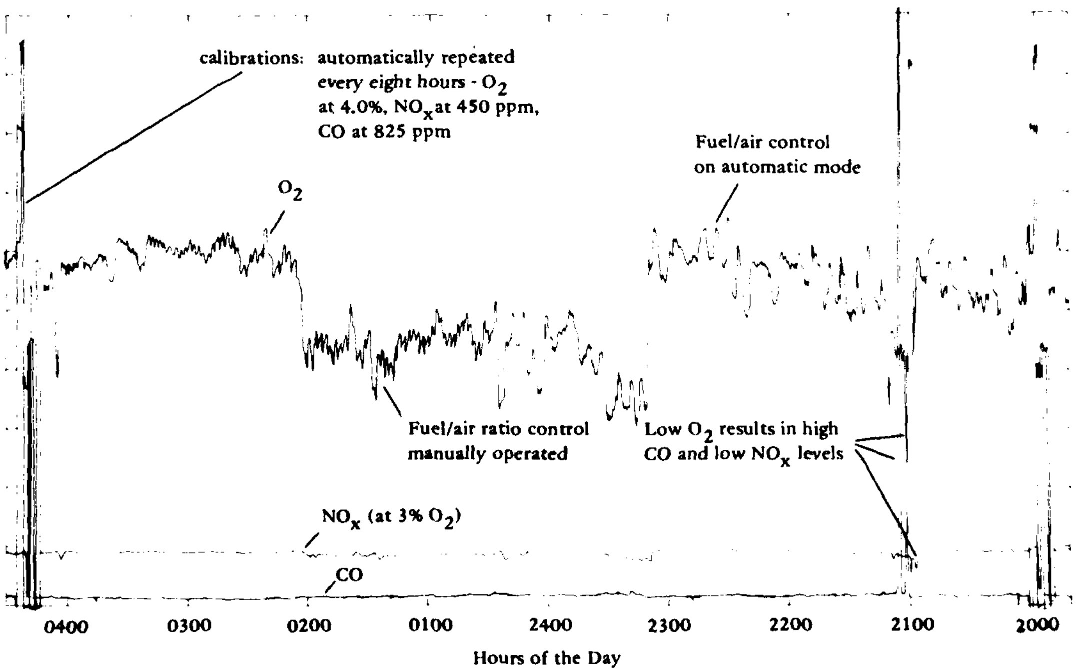
(a) Front view



(b) Interior view (from rear)

Figure 6. Stack gas monitoring instrumentation.

(c) Sampling probe installation




(d) Typical output

Figure 6. Continued

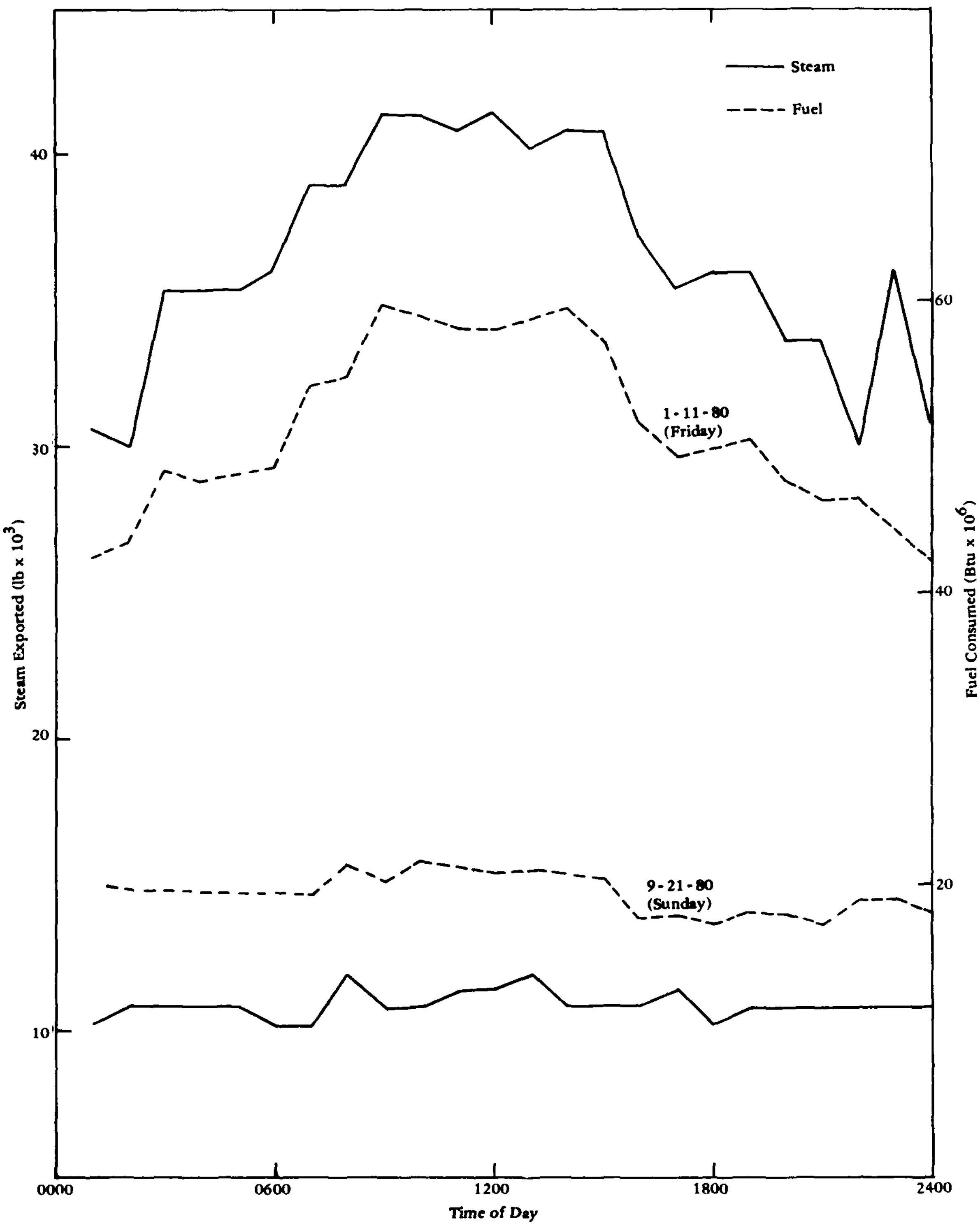



Figure 7. Highest and lowest daily profiles for steam exported and fuel consumed during FY 80 at Building K-212, NAS Miramar. (Only waste oils were used during these days.)

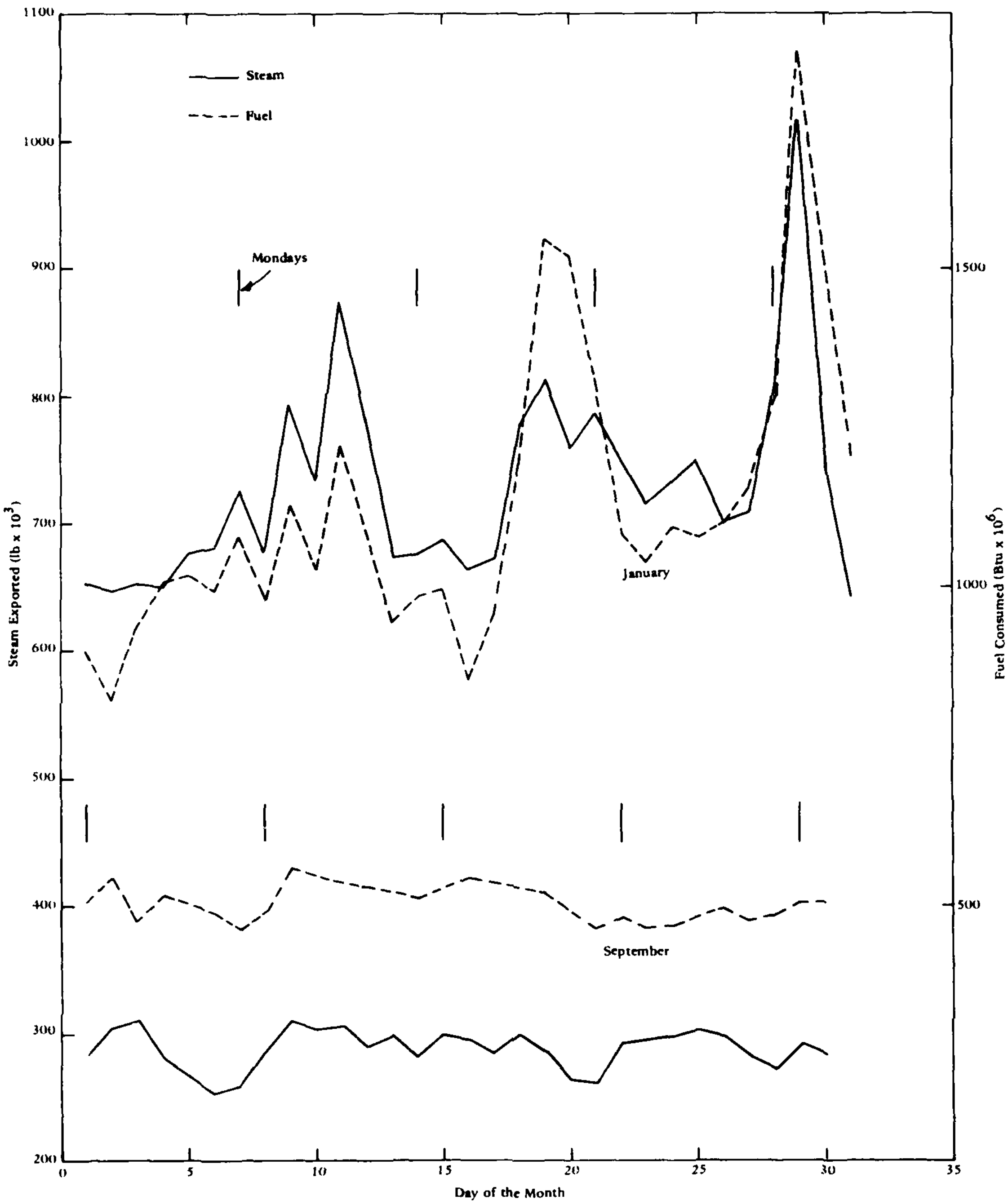
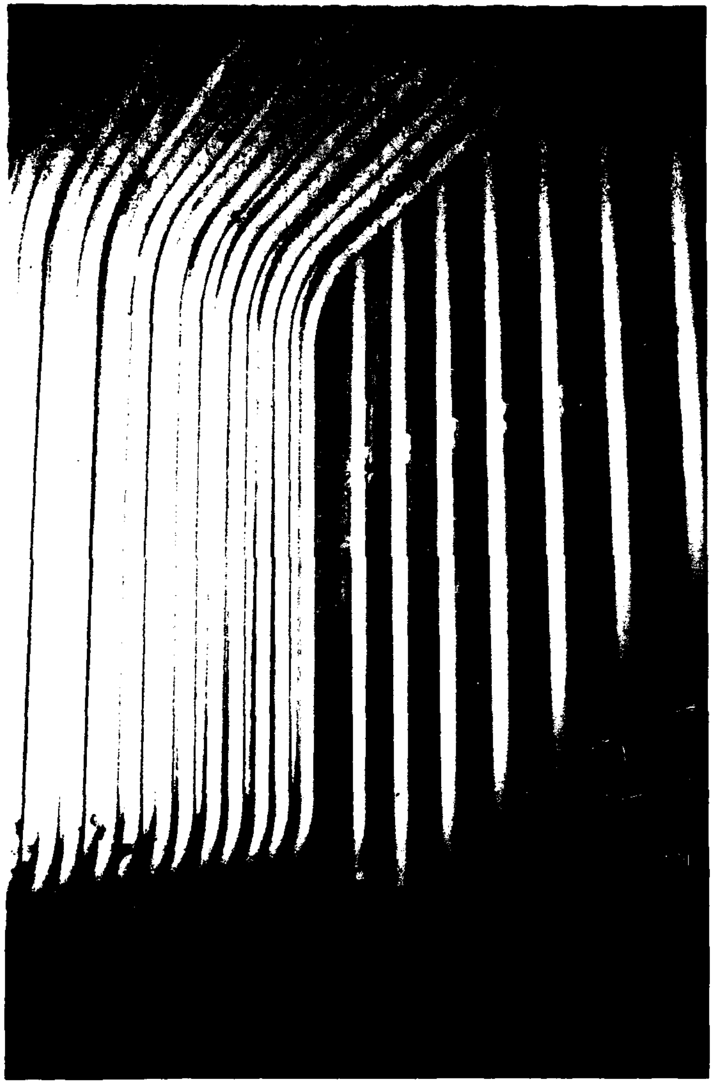



Figure 8. Highest and lowest monthly profiles for steam exported and fuel consumed during FY80 at Building K-212, NAS Miramar. (61% of the total energy consumed in January and 100% in September was waste oils.)



(a) Furnace region opposite burners

(b) Close up view of green scaly deposit

Figure 9. Deposits on boiler tubes.

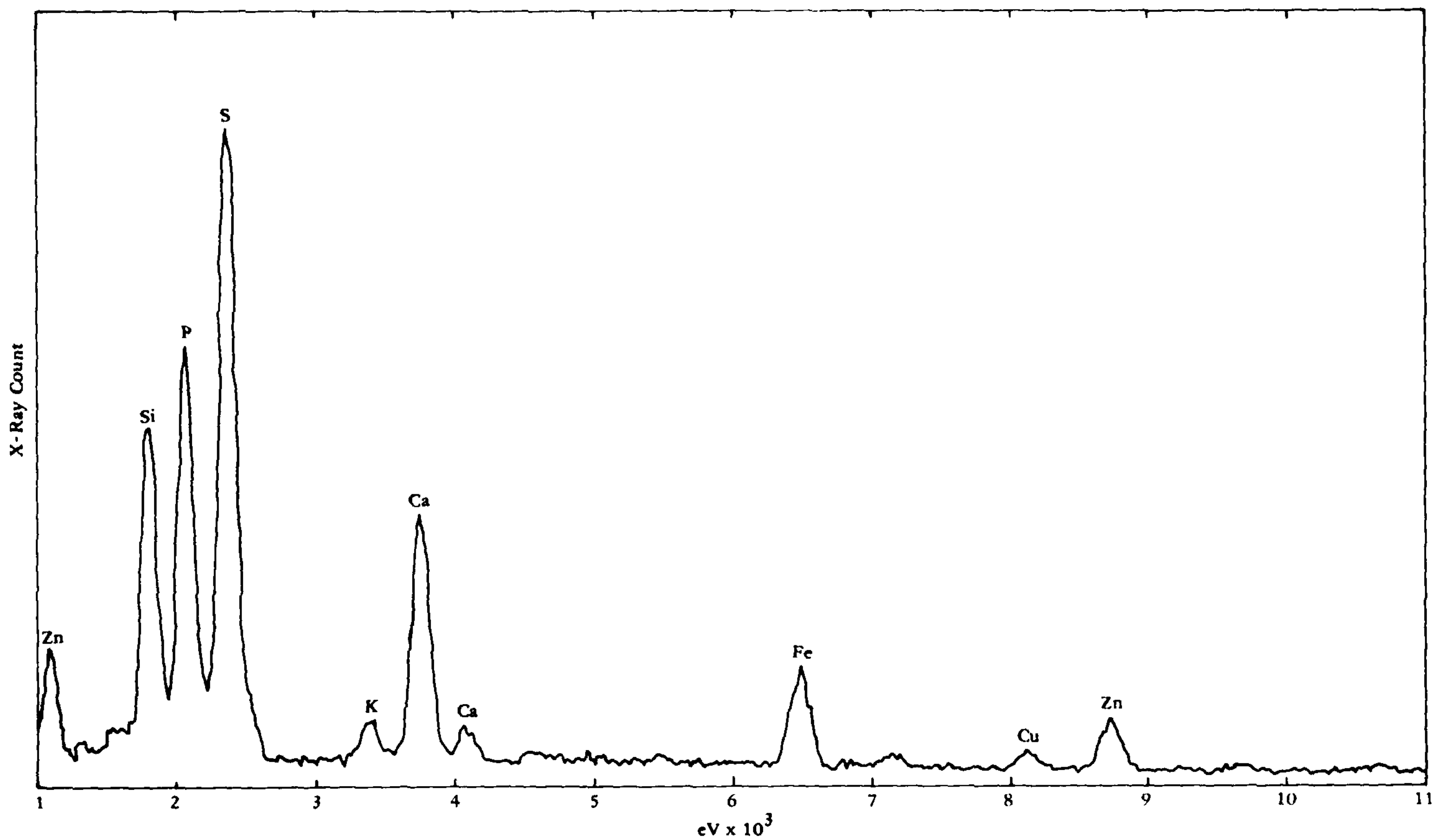



Figure 10. Energy dispersive X-ray analysis of boiler tube deposit (a typical result).

## DISTRIBUTION LIST

AFB (AFIT LDE), Wright Patterson OH; 82ABG DEMC, Williams AZ; ABG DEE (F. Nethers), Goodfellow AFB TX; AFESC DEB, Tyndall, FL; CESCH, Wright-Patterson; MAC DET (Col. P. Thompson) Scott, IL; SAMSO MNND, Norton AFB CA; Samso Dec (Sauer) Vandenburg, CA; Stinfo Library, Offutt NE
ARMY ARRADCOM, Dover, NJ; DAEN-CWE-M (LT C D Binning), Washington DC; DAEN-MPE-D Washington DC; DAEN-MPU, Washington DC; ERADCOM Tech Supp Dir. (DELSD-L) Ft. Monmouth, NJ; Natick R&D Command (Kwoh Hu) Natick MA; Tech. Ref. Div., Fort Huachuca, AZ
ARMY - CERL Library, Champaign IL
ARMY CORPS OF ENGINEERS MRD-Eng. Div., Omaha NE; Seattle Dist. Library, Seattle WA
ARMY ENGR DIST. Library, Portland OR
ARMY MISSILE R&D CMD SCI Info Cen (DOC) Redstone Arsenal, AL
ASO PWD (ENS M W Davis), Phildadelphia, PA
CINCLANT Civil Engr. Supp. Plans. Ofr Norfolk, VA
CINCPAC Fac Engrng Div (J44) Makalapa, HI
CNAVRES Code 13 (Dir. Facilities) New Orleans, LA
CNM Code MAT-04, Washington, DC; Code MAT-08E, Washington, DC; NMAT - 044, Washington DC
CNO Code NOP-964, Washington DC; Code OP 987 Washington DC; Code OP-413 Wash, DC; Code OPNAV 09B24 (H); OP-098, Washington, DC; OP987J (J. Boosman), Pentagon
COMFLEACT, OKINAWA PWD - Engr Div, Sasebo, Japan; PWO, Kadena, Okinawa
COMNAVMARIANAS Code N4, Guam
COMOCEANSYSPAC SCE, Pearl Harbor HI
DEFFUELSUPPCEN DFSC-OWE (Term Engrng) Alexandria, VA
DOE INEL Tech. Lib. (Reports Section), Idaho Falls, ID
DTIC Defense Technical Info Ctr Alexandria, VA
DTNSRDC Code 522 (Library), Annapolis MD
ENVIRONMENTAL PROTECTION AGENCY Reg. III Library, Philadelphia PA
FLTCOMBATTRACENLANT PWO, Virginia Bch VA
FMFLANT CEC Offr, Norfolk VA
LIBRARY OF CONGRESS Washington, DC (Sciences & Tech Div)
MARINE CORPS BASE Code 406, Camp Lejeune, NC; PWD - Engr Div, Camp Pendleton, CA; PWD - Maint. Control Div, Camp Butler, Kawasaki, Japan; PWO Camp Lejeune NC; PWO, Camp S. D. Butler, Kawasaki Japan
MARINE CORPS HQS Code LFF-2, Washington DC
MCAS CO, Kaneohe Bay HI; Code S4, Quantico VA; Facs Maint Dept - Operations Div, Cherry Point; PWD - Utilities Div, Iwakuni, Japan; PWO, Yuma AZ
MCDEC NSAP REP, Quantico VA
MCLB B520, Barstow CA; PWO, Barstow CA
MCRD PWO, San Diego Ca
NAF PWD - Engr Div, Atsugi, Japan; PWO Sigonella Sicily; PWO, Atsugi Japan
NALF OINC, San Diego, CA
NARF Code 612, Jax, FL
NAS Code 114, Alameda CA; Code 187, Jacksonville FL; Code 18700, Brunswick ME; Code 18U (ENS P.J. Hickey), Corpus Christi TX; Code 70, Atlanta, Marietta GA; Dir. Util. Div., Bermuda; Grover, PWD, Patuxent River, MD; Lakehurst, NJ; Lead. Chief. Petty Offr. PW/Self Help Div, Beeville TX; PW (J. Maguire), Corpus Christi TX; PWD - Engr Div Dir, Millington, TN; PWD - Engr Div, Gtmo, Cuba; PWD - Engr Div, Oak Harbor, WA; PWD Maint. Cont. Dir., Fallon NV; PWD, Maintenance Control Dir., Bermuda; PWD, Willow Grove PA; PWO Belle Chasse, LA; PWO Chase Field Beeville, TX; PWO Key West FL; PWO Whiting Fld, Milton FL; PWO, Cubi Point, R.P.; PWO, Dallas TX; PWO, Glenview IL; PWO, Kingsville TX; PWO, Millington TN; PWO, Miramar, San Diego CA; PWO., Moffett Field CA; SCE Norfolk, VA; SCE, Barbers Point HI; Shore Facil. Ofr Norfolk, VA
NATL RESEARCH COUNCIL Naval Studies Board, Washington DC
NATNAVMEDCEN Code 43 (PWO) Bethesda, MD
NAVACT PWO, London UK
NAVACTDET PWO, Holy Lock UK
NAVAEROSPREGMEDCEN SCE, Pensacola FL
NAVAIRDEVCEN PWD, Engr Div Mgr, Warminster, PA; PWO Warminster, PA

NAVAVIONICFAC PW Div Indianapolis, IN; PWD Deputy Dir. D 701, Indianapolis, IN
NAVCOASTSYSTCTR Library Panama City, FL
NAVCOMMAREAMSTRSTA PWO, Norfolk VA; PWO, Wahiawa HI; SCE Unit 1 Naples Italy
NAVCOMMSTA CO (61E) Puerto Rico; Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWD-ENG Div Dir, Washington, DC; PWO, Exmouth, Australia; PWO, Fort Amador Panama Canal
NAVCOMMU PWO, Thurso, Scotland
NAVEDTRAPRODEVCEN Technical Library, Pensacola, FL
NAVEDUTRACEN Engr Dept (Code 42) Newport, RI
NAVFAC PWO, Brawdy Wales UK; PWO, Cape Hatteras, Buxton NC; PWO, Centerville Bch, Ferndale CA; PWO, Guam
NAVFAC PWO, Lewes DE
NAVFAC PWO, Point Sur, Big Sur CA
NAVFACENGCOM Code 032 (Essoglou) Alexandria, VA; Code 043 Alexandria, VA, Code 044 Alexandria, VA; Code 0454B Alexandria, Va; Code 04B3 Alexandria, VA; Code 051A (B Henbring) Alexandria, VA; Code 1113 (T. Stevens) Alexandria, VA; code 08T Alexandria, VA
NAVFACENGCOM - CHES DIV. Code 112 Washington, DC; Code 403 Washington DC; Code 405 Wash, DC, FPO-1 Washington, DC
NAVFACENGCOM - LANT DIV. CDR E. Peltier; Code 111, Norfolk, VA, Eur. BR Deputy Dir, Naples Italy; RDT&ELO 102, Norfolk VA
NAVFACENGCOM - NORTH DIV. Code 04 Philadelphia, PA; Code 09P Philadelphia PA, Code 1028, RDT&ELO, Philadelphia PA; Code 111 Philadelphia, PA
NAVFACENGCOM - PAC DIV. (Kyi) Code 101, Pearl Harbor, HI; CODE 09P PEARL HARBOR HI, Code 2011 Pearl Harbor, HI; Code 402, RDT&E, Pearl Harbor HI; Commander, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 403, Gaddy, Charleston, SC; Code 90, RDT&ELO, Charleston SC
NAVFACENGCOM - WEST DIV. Code 04B San Bruno, CA; O9P/20 San Bruno, CA, RDT&ELO Code 2011 San Bruno, CA
NAVFACENGCOM CONTRACT AROICC, Quantico, VA
NAVFORCARIB Commander (N42), Puerto Rico
NAVHOSP PWD - Engr Div, Beaufort, SC
NAVMAG PWD - Engr Div, Guam; SCE, Guam; SCE, Subic Bay, R.P
NAVOCEANSYSCEN Code 4473 Bayside Library, San Diego, CA; Code 4473B (Tech Lib) San Diego, CA
NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM
NAVORDSTA PWD - Dir, Engr Div, Indian Head, MD; PWO, Indianhead, MD, PWO, Louisville KY
NAVPETOFF Code 30, Alexandria VA
NAVPHIBASE SCE, Coronado, San Diego CA
NAVRADRECFAC PWO, Kami Seya Japan
NAVREGMEDCEN PWD - Engr Div, Camp Lejeune, NC; PWO Newport RI, PWO Portsmouth, VA
NAVREGMEDCEN PWO, Okinawa, Japan
NAVREGMEDCEN SCE (D. Kaye); SCE San Diego, CA; SCE, Camp Pendleton CA, SCE, Guam, SCE, Oakland CA
NAVREGMEDCEN SCE, Yokosuka, Japan
NAVSCOLCECOFF C35 Port Hueneme, CA; CO, Code C44A Port Hueneme, CA
NAVSCSOL PWO, Athens GA
NAVSEASYSCOM SEA 04E (L Kess) Washington, DC; SEA05E1, Washington, D.C
NAVSECGRUACT Facil. Off., Galeta Is. Panama Canal; PWO, Adak AK; PWO, Edzell Scotland, PWO, Puerto Rico; PWO, Torri Sta, Okinawa
NAVSECSTA PWD - Engr Div, Wash., DC
NAVSHIPREPFAC SCE Subic Bay
NAVSHIPYD Code 202.4, Long Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 380, Portsmouth, VA; Code 382.3 (R. Law) Pearl Harbor, HI; Code 400, Puget Sound; Code 410, Mare Is., Vallejo CA; Code 440 Portsmouth NH; Code 440, Norfolk; Code 440, Puget Sound, Bremerton WA; Code 450, Charleston SC; Code 453 (Util. Supr), Vallejo CA; Library, Portsmouth NH; PW Dept, Long Beach, CA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI
NAVSTA CO Naval Station, Mayport FL; CO, Brooklyn NY; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Div. Dir Code 531, Rodman Panama Canal; PWD - Engr Dept, Adak, AK; PWD - Engr Div, Midway Is.; PWO Pearl Harbor, HI; PWO, Guantanamo Bay Cuba; PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam; SCE, San Diego CA; SCE, Subic Bay, R.P.

NAVSUBASE ENS S. Dove, Groton, CT; SCE, Pearl Harbor HI
NAVSUPPACT PWO Naples Italy; PWO, Seattle, WA; Plan Engr Div., Naples Italy
NAVSUPPFAC PWD - Maint. Control Div. Thurmont, MD
NAVSUPPO PWO, La Maddalena, Italy
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVUSEAWARENGSTA Keyport, WA
NAVWPNCEN Code 2636 (W. Bonner), China Lake CA; Code 3803 China Lake, CA; PWO (Code 266) China Lake, CA
NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Concord CA; Code 092A (C. Fredericks) Seal Beach CA; Maint. Control Dir., Yorktown VA
NAVWPNSTA PW Office (Code 09C1) Yorktown, VA
NAVWPNSTA PWD - Maint Control Div. Charleston, SC; PWD - Supr Gen Engr, Seal Beach, CA; PWO, Charleston, SC; PWO, Seal Beach CA
NAVWPNSUPPCEN Code 09 Crane IN
NCBC Code 10 Davisville, RI; Code 25111 Port Hueneme, CA; Code 400, Gulfport MS; Code 430 (PW Engrng) Gulfport, MS; NEESA Code 252 (P Winters) Port Hueneme, CA; PWO (Code 80) Port Hueneme, CA; PWO, Davisville RI
NMCB FIVE, Operations Dept; THREE, Operations Off.
NRL Code 5800 Washington, DC
NSD SCE, Subic Bay, R.P.
NUSC Code EA123 (R.S. Munn), New London CT
OFFICE SECRETARY OF DEFENSE OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR (Scientific Dir) Pasadena, CA; Code 221, Arlington VA; Code 700F Arlington VA
PACMISRANFAC HI Area Bkg Sands, PWO Kekaha, Kauai, HI
PWC CO Norfolk, VA; CO, (Code 10), Oakland, CA; CO, Great Lakes IL; CO, Pearl Harbor HI; Code 10, Great Lakes, IL; Code 110, Oakland, CA; Code 120C, (Library) San Diego, CA; Code 154, Great Lakes, IL; Code 200, Great Lakes IL; Code 200, Guam; Code 220.1, Norfolk VA; Code 30C, Norfolk, VA; Code 505A (H. Wheeler); Code 600 (Utilities Dept) Norfolk, VA; Code 600, Great Lakes, IL; Code 601, Oakland, CA; Code 610, San Diego Ca; Library, Subic Bay, R.P.; Util Dept (R Pascua) Pearl Harbor, HI; Utilities Officer, Guam
SPCC PWO (Code 120) Mechanicsburg PA
SUPANX PWO, Williamsburg VA
USCG (Smith), Washington, DC; G-MMT-4/82 (J Spencer)
USNA Ch. Mech. Engr. Dept Annapolis MD; Energy-Environ Study Grp, Annapolis, MD; Mech. Engr. Dept. (C. Wu), Annapolis MD; PWD Engr. Div. (C. Bradford) Annapolis MD; PWO Annapolis MD